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CODE IDENT. NO. 81205

NUMBER D180-17523-1

TITLE: THE ADVANCED TECHNICAL DATA RESEARCH STUDY

PHASE I

ABSTRACTS OF AVAILABLE DATA

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PREPARED BY *D.R. Duren*  
D. R. Duren

SUPERVISED BY *D.A. Mowrer*  
D. A. Mowrer

APPROVED BY *P.H. Grelow*  
P. H. Grelow

APPROVED BY *A.W. Varunok*  
A. W. Varunok

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## INTRODUCTION

The Advanced Technical Data Research Study was implemented in March 1973. The objectives were to evaluate new techniques and devices for developing and transmitting the technical data required to operate and maintain weapon systems and to determine what new concepts should be considered for application to future programs in order to provide accurate data on a timely basis at least cost. The study was to be conducted in two phases:

PHASE I - Studies made by government agencies and industry groups on product support technical data problems and on proposed advanced concepts, techniques and devices for support data preparation; transmittal and retrieval will be researched, and published data thereon acquired. A document listing data acquired and containing abstracts of pertinent data will be released.

PHASE II - Phase I data will be analyzed to the extent necessary to single out the most promising concepts, techniques and devices for support data preparation, transmittal and retrieval. That data will be modified and combined in order to develop the most promising advanced technical data system. The system, along with its rationale, will be documented and will include cost considerations. The document will include specific recommendations on the concepts, techniques and devices that should be applied.

The approach taken to complete Phase I is as follows:

- Research existing studies on technical data problems by government and industry.
- Contact selected personnel in government and industry to acquire knowledge of problems, experimental activity, results of prior studies, trends and anticipated future requirements, all of which may or may not be documented.
- Institute a library search of all pertinent technical data available in the Boeing libraries, Experience Analysis Center and the Defense Documentation Center (DDC).
- Develop a practical approach to the resolution of one or more technical data problem areas.
- Establish a list of criteria to be used for system selection.

Of all the data reviewed, the significant items were abstracted and the list provided in Appendix A.

Personnel contacted within industry and government are listed in Appendix B. Personnel contacted within The Boeing Company are not listed, but the information gained from them has been substantial.

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Also provided in Appendix C are the results of an industry survey conducted by "The National Security Industrial Association" for the Department of Defense. It provides a good insight into the technical manual industry. It also provides a background for the development of this study.

Not included in this report is the data area associated with automatic test and diagnostic equipment. The impact on data by developments in this area could be very profound. Nevertheless, it is not a direct function of a technical data program. To gain an insight into the possible effects of this equipment on the future technical data systems, automatic test equipment systems such as Electronic Quality Assurance Test Equipment (EQUATE), Land Combat Support Systems (LCSS), Automated Test Systems Jet Engine Accessories (ATSJEA), Automatic Test Systems (ATS) etc. were reviewed for background information for both Phase I and II of this study.

The typical technical data program from proposal to obsolescence involves a great variety of activities with many agencies, both government and industry, participating. For purposes of evaluation and study, the total publication activities have been grouped into these major segments:

- Conceptual Phase (Government and Industry)
- Production Phase (Industry)
- Use Phase (Government)

The abstracts associated with each major publications segment are included with the explanation of the segment. Some abstracts overlap the arbitrary division and are included in the segment with the greatest impact.

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**CONCEPTUAL PHASE  
ABSTRACTS**

This segment is the grouping of technical publication activities such as determining data requirements, selection of specifications, contractual activities, development of source data, administrative functions required to implement a program, and development of the maintenance technical data.

In this area, the greatest amount of effort has been expended in long term studies, tests and evaluations of basic concept changes. This area is also the most difficult in which to implement change because it usually involves a change or deviation to either a detail or basic specification. To fully develop a new specification and process it through implementation, at present, requires a time span of five to ten years.

The following abstracts are of concepts that have been under investigation for a number of years. Some, like the concept of Job Performance Aids, have been tested extensively. Yet, at the present time, this concept has not been accepted by the Services as an advancement of technical data "state-of-the-art."

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PIMO - Presentation of Information for Maintenance and Operation (Ref. 20)

This document presented the dilemma facing military operation and maintenance personnel. As specialization intensified, due to exploding technology, communication and understanding were soon recognized as major problems. The crises created by manpower shortages, increasing technical specialization requirements (and the resultant training and data) and the urgent demands for reducing costs caused by duplication of effort, and worse, duplication of errors, have combined to focus on the following solution. Rapid information retrieval and display is the proper avenue for solving this maintenance information dilemma. While the information retrieval and display state-of-the-art has advanced spectacularly in the past decade, the military technical manual applications have remained essentially static. However, the Air Force PIMO, Army AVIS and Navy SIMM and other technical manual studies, and the Viet Nam war maintenance problems have awakened a wide-spread interest in improved maintenance information presentation systems.

PIMO is more than a single concept or system for advancing the state-of-the-art in technical orders. It is a combination of concepts developed by an Air Force Working Group under the general direction of DSC/System Support Division, Headquarters AFSC. Two prime contractors, R. Parsons Engineering Co. and Serendipity Associates, conducted parallel feasibility studies on the BUIC system and the UH-1F helicopter program. These parallel studies tested a number of individual T.O. concepts such as pocket size manuals, audio-visual data presentation systems, troubleshooting aids, SIMM maintenance dependency charts and data collection.

The PIMO Project was initiated over eight years ago and millions of dollars have been spent to accomplish one basic objective - to provide, in an optimum fashion, the information needed to maintain Air Force systems and equipment. PIMO is not a technical manual study that will pass into oblivion with no effect on the technical manual specifications and criteria. Project PIMO will result in changes to future technical manual systems and criteria for the following reasons:

- a. The project uses microforms that have the following recognized advantages: storage space is small, image carriers can be manipulated rapidly and automatically, images can be easily reproduced individually while keeping the collection complete and the microimages can be easily updated and shipped to point of use where new and changed pages can be quickly reviewed. The "Information Transfer Revolution" can not be ignored!
- b. The project is based on sound psychological studies in the areas of perception, short-term memory and learning which cannot be ignored as they have been and are being successfully applied in the educational world and industry. The existing technical manual specifications are not based on current psychological knowledge.

- c. The concepts recognize that the computer will revolutionize fault analysis or technical manual troubleshooting. Computer-aided fault analysis by optimizing the parameters of skill level, symptomology, reliability statistics and maintainability will result in troubleshooting information that will be logical, faster and specific to the situation.
- d. PIMO recommended the use of electronic images for certain technical manual applications. These images can be instantly stored by linear scanning, with the scan tract signals stored on magnetic tape. This data can be retrieved for T-V type monitoring or electrostatically reproduced in hardcopy.

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A Critique of Project PIMO by The Boeing Company (Ref. 26)

The salient points of the critique are presented in edited form directly from the document.

CRITIQUE BASELINE

The following critique is based on review of the overall PIMO Program and its application to the C-141A aircraft system. It was not possible to obtain any official PIMO evaluations by the military agencies or the commercial airlines. The Army, Navy and airlines visited the PIMO test sites and critiqued the program. However, no published reports were available and the following comments are based on a cursory review of various Serendipity Associates developed PIMO/C-141A maintenance information and the official PIMO planning information cited in the Bibliography provided at the end of this document.

CRITIQUE FACTORSScope

A quick review of the PIMO Program indicates that the scope of the PIMO test program was too broad. Too many items were being evaluated. The PIMO Program attempted to test, compare and evaluate five distinctly different technical manual presentation modes; i.e., pocket-size print, audio, visual (MICRO-VUE), SIMM maintenance dependency troubleshooting charts and conventional technical orders. In addition, complex and non-field tested audio-visual equipment had to be evaluated. Two levels of maintenance (Organizational and Field) were initially part of the program. The field level tests were eventually cancelled. Next, they attempted to develop and evaluate a computerized maintenance management information and control system which was to be part of the Air Force MMICS program. This involved AFTO 200 data collection. This included a Centralized Activity Reporting System (CARS) which automatically documented the maintenance information and completed the AFTO 210/211/212 forms. The CARS and Maintenance Information Recording Center (MIRC) innovations inherent in the PIMO Program were valid and worthwhile high priority items that needed to be developed and tested. However, adding these developments and evaluations to a technical manual presentation test program greatly increased the scope of the PIMO Program. The same could be said of the PIMO Basic Technical Data Storage (BTDS) Program. This concept was worthy of development and testing as a separate item. However, to develop and test a computerized technical manual configuration/production control system for a "reformatting" type program was another unnecessary expansion of the development program's scope.

Test Contractor

The test contractor was a small company that had never managed a large technical manual development/production program and lacked the experience necessary to efficiently convert the C-141A manuals into PIMO format. Their assumption (stated in meetings with Boeing personnel) that they could use non-engineering

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types with no direct link with the prime contractor's design personnel was not valid. Even with the verified Lockheed-prepared C-141A technical manuals in hand, direct liaison with the C-141 design, test and logistics personnel was a necessity. This is borne out by the Aerospace Industry Association's (AIA) March 1968 study entitled, "Subcontracting/Competitive Procurement of Technical Manuals." Some of the AIA study conclusions were as follows:

"On large technical manuals such as maintenance manuals for a complete weapon system, all of the background information required by the subcontractor to accomplish the work cannot be furnished. This can only be done properly by the prime contractor since a subcontractor does not have access to all the data needed and cannot obtain this data without actually working at the prime contractor's facility."

"Results from data houses are not satisfactory because the data to be incorporated in the manuals cannot be extracted readily from existing approved documents."

The SIMM MDC troubleshooting charts employed in the PIMO Program require considerable skill and experience to produce and direct liaison with the designers. Many feel that MDCs must be initially prepared by design and system engineering personnel. The test contractor felt the MDCs per MIL-M-24100A were not adequate in all cases and they supplemented the MDCs with conventional "symptom-cause" tables and other troubleshooting information. Other programs have successfully used MDCs as the sole troubleshooting aid in technical manual tests. Also, as the PIMO Program progresses, the number of maintenance technical manual supplements increases. Separate training guides and training texts were also released. It appears that valid test conclusions will be difficult for the test contractor to obtain, since there are many variables and few constants. The test contractor did not state how they were going to measure the MDC test results despite the fact that there are numerous detailed SIMM/MDC test documents available (see Bibliography) describing how the Coast Guard, Navy, Air Force, Army and others conducted controlled MDC tests.

#### Job-Oriented Manual Concept

The PIMO Program resurrected the "job-oriented" technical manual concept that had been tried and tested but not vindicated in the 1950's on aircraft and missile programs. The job-oriented concept is a departure from the conventional system/equipment technical manual approach. The job-oriented or "job-guide" approach is essentially one of presenting maintenance information to the user while he is performing the job.

#### Summary

Other items of significance identified during PIMO studies are as follows:

- a. The presentation equipment (MICRO-VUE) selected was not environmentally tested to military standards. Hence, its reliability was low. The magnification factor (260:1) was too high, resulting in resolution problems. A dual magnification capability and the ability to retrieve double or single image displays is desirable. Rugged, light and easy to use storage/display equipment is mandatory.

- b. An audio system is not required. This was proven in the Army AVIS and other studies.
- c. The communication link from the on-site maintenance points to maintenance control should not be part of the display system. The PIMO "walkie-talkie" approach is not recommended. All of these management assignment/reporting functions (and related equipment requirements) only increased the complexity and scope of the PIMO tests.
- d. The PIMO "mini" approach (reducing the amount of technical manual information provided the maintenance man) was a step in the right direction. The Army (checklist concept) and others are testing other "mini" approaches. It appears that this concept was not successfully developed or demonstrated. What is the minimum amount of maintenance information required in the field? PIMO does not provide the answer. The early Phase II tests and development studies apparently concluded that the PIMO concept described in the Phase IA criteria and specifications, did not have enough descriptive/maintenance information. Thus, additional printed "conventional" technical manual information was added as the tests progressed. Another PIMO concept called the "imbedded technique" related to the "mini" approach. The PIMO developers claimed you had to first reduce the amount of maintenance information and then "imbed" only the necessary information for a given activity. This depended on a complete analysis of the man-machine maintenance relationships. This "imbedding - mini" approach was not successfully accomplished, and it soon became apparent that the simple step-by-step maintenance instructions designed for the grade 3 maintenance man was anathema to the grade 5 or 7.

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CATS - Computer Assisted Troubleshooting (Ref. 2)

This is a system that uses a remotely located computer and microfiche reader to troubleshoot systems with inexperienced personnel. This system was conceived by Boeing Vertol. An experimental test was conducted by the Army at Fort Eustis, Virginia, on a CH-47A Helicopter, specifically the APU. This was a "one shot test" with no follow-up. The test conclusions were:

1. Inexperienced men can successfully perform Computer Aided Troubleshooting (CATS). CATS is a feasible technique.
2. Inexperienced men without CATS would not be able to perform troubleshooting except in those cases where the individual involved had an inherent aptitude for troubleshooting. However, even then the fault isolation time would be lengthy.
3. There is a risk that a completely untrained man will make a mistake; e.g., misreading an ohmmeter and causing the computer to find a wrong trouble.
4. For certain types of troubles the CATS medium is superior to expert men without the computer.
5. In most cases expert personnel can take advantage of experience; i.e., learned shortcuts to accomplish troubleshooting in less time than can be done with CATS.
6. In its present form, CATS uses a system of hardware that is not well suited to forward field usage. Improvements like miniaturization, portability, hardcopy printout, freedom from phone lines; i.e., radio data link, and a self-contained power supply, would need to be incorporated before the hardware could be considered fully practical.
7. CATS programming could be written in a more proficient manner, and the logic could be improved through experience with this medium and by careful validation procedures.
8. CATS can incorporate a few "quickie" tests to look rapidly for the more common faults before reverting to a systematic logic tree that will ferret out all troubles. This procedure would thus incorporate some of the shortcuts available to field trained expert troubleshooters.
9. Though the CATS system is not primarily a training medium, it will teach each troubleshooter a limited amount of troubleshooting know-how. This would eventually enable the man to troubleshoot by himself.

Disadvantages of CATS

1. Cost of software preparation is very high as compared to preparation for classroom or on-the-job instruction.

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2. The computer will normally find some kind of fault. It will find the wrong fault if the CATS operator makes a faulty observation and thus enters bad data. CATS operators may also read a question wrong and send the wrong answer to the computer.
3. The CATS program will normally follow a routine that consumes a considerable span of time.
4. Debugging and validating a computer program requires the use of hardware for extensive periods of time. Validation can only be done with operational equipment, but such operating equipment is difficult to obtain for periods long enough to complete the tedious testing required for validation.

#### Advantages of CATS

1. The combined talents of several expert and experienced troubleshooters can be incorporated into the logic and software of a computerized program. Their considerable combined analytical capability can be incorporated in the analysis portions of the computer program and thus put to good use by a large number of inexperienced men.
2. The manpower base of an organizational unit can be expanded with the aid of CATS. That is, inexperienced men can successfully accomplish the art of troubleshooting, a task they were heretofore unable to cope with. This provides the opportunity to put them to work at tasks which are otherwise beyond their ability, and thereby relieve the workload on the few highly capable men usually available in a squadron.
3. The computer software can be edited or updated readily. This permits changes in the program as the need for correction is detected or as field changes are incorporated in the equipment.

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FORECAST (Refs. 44 & 48)

FORECAST was developed by the Human Resources Research Office (HumRRO) under contract to the Department of the Army.

FORECAST is a troubleshooting technique that provides guidance through a blocking process that shows each part that could be causing the malfunction. The guidance is such that the repairman can do his own thinking, yet benefit from the deductions made by experienced system analysts who have structured the system in the best manner possible for troubleshooting.

The FORECAST concept features five basic elements: troubleshooting block diagram (TBD), technical story, waveform guide, blocked schematic and resistance chart. The first two elements (TBD and technical story) are used in the first step of troubleshooting to localize the trouble to an area of about four blocks (about 5% of the system). The waveform guide is used in the second step to localize the trouble to a single block schematic, and the resistance chart is used in the third step to test parts within a block in order to identify the bad one(s).

FORECAST Troubleshooting Block Diagram

Troubleshooting Block Diagrams support the process of:

1. Interpreting symptoms in terms of areas of the equipment that might contain the malfunction causing the symptom.
2. Selecting checkpoints to isolate a trouble to a block through showing the output of each block and where to measure it. There is also a number on each output that refers the repairman to the waveform guide for detailed instructions for making the output measurement.

FORECAST Technical Story

1. Describes in summary form how the signal into a block is transformed into its output.
2. Describes all the sources of symptoms (output of blocks) that can be identified by the repairman on a scope, meter and the like.

FORECAST-Waveform Guide

1. Giving checkpoint locations.
2. Indicating what test equipment to use, settings of test equipment, operational mode of systems and any special testing procedures or instructions required.
3. Listing standard or normal readings from which to compare obtained results.
4. Indicating special test conditions such as control settings, tube removed and so forth.

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FORECAST Blocked Schematics

Blocked schematics are conventional schematics which are "blocked" so that all parts that will affect a given block's output are grouped within a selected area. The system analysts have already determined which parts belong in each block. When the schematics are blocked, the maintenance man is assured that the parts in a given block are the only ones that could be causing the trouble. The highly unreliable parts and the easily checked parts, such as tubes, are checked first. If this does not identify the source of the trouble, the system is deenergized and all chassis inputs are grounded for further measurements. The deenergized tube isolates parts that are attached to tube pins. The resistance value on each tube pin can then be measured and compared to the correct value for each tube pin as recorded in the resistance chart. The pin having an out-of-tolerance resistance value has one or more bad parts attached to it. Those parts are measured individually and the out-of-tolerance part is replaced, thus repairing the system.

FORECAST Resistance Chart

Resistance charts provide normal pin readings.

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JPA's - Job Performance Aids (Refs. 3, 4, 5, 16, 23 & 29) -

A series of research efforts conducted by the Air Force Human Resources Laboratory has resulted in the development of a new type of maintenance data known as fully proceduralized job performance aids (JPAs). Available evidence suggests that application of fully proceduralized JPAs to the maintenance of Air Force systems will significantly increase maintenance effectiveness. A well defined technology has been developed for the preparation of fully proceduralized JPAs. This technology differs significantly from the techniques used to develop conventional technical orders.

The two major types of JPAs are Job Guides and Fully Proceduralized Troubleshooting Aids.

Job Guides provide instructions for fixed-procedure tasks such as checkout, adjustment, removal and replacement. The instructions are presented in a step-by-step format and are supported by detailed illustrations.

The term "fully proceduralized troubleshooting" describes a method for isolating equipment malfunctions, wherein the selection and sequence of tests or checks is controlled by a preset procedure. The procedure is usually arranged so that the result of a specified test or check determines which test or other action is next performed. The number of branches or alternative checks at a choice point is typically two, but there may be as many branches as there are possible outcomes of the test.

The principle underlying the usefulness of proceduralized troubleshooting is simplification of the job through elimination or reduction of deductions, discriminations, interpolations and decisions which the technician would otherwise have to produce. They are produced before the fact and incorporated in the performance aids. When this is done, the technician need only "look up" the information he requires instead of generating it himself. Since he is not required by the job to generate the information, he does not have to be able to do so.

Development of JPAs has several salient features that differ in degree or in kind from development of conventional technical orders.

The overall process of developing advanced-type JPAs begins with development of a data base through a process called "Task Analysis," which consists of three major steps. The first is preparation of a Task Identification Matrix (TIM). The TIM is a matrix of all equipment end items maintainable at the organizational level of maintenance versus all types of organizational maintenance tasks. It identifies all of the theoretical possibilities for tasks at that level of maintenance. It thus tends to insure that no tasks will be overlooked in the JPA.

In the second step, a list of actual organizational-level tasks (not just theoretical possibilities) is extracted from the TIM, in accordance with certain criteria, to form the Task Inventory. The Task Inventory is the list of tasks for which JPA must be prepared.

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The third step in the process consists of collecting many different kinds of information about each task in the Task Inventory. The kinds of information required are stated in the draft specification. This information is either recorded on, or referenced in, the Task Description Index and Management Matrix (TDIMM). This document, along with all of the documents referenced in it, provides the data base upon which all JPA elements are built.

The three steps described above must generally be done in serial order, although it is obvious that some overlap is possible. For example, task description data can be collected about tasks that have been identified before all tasks have been identified. The steps in preparation of the various types of JPA can then proceed in parallel, assuming that the data base is there to support their development.

Preparation of the Job Guides consists mainly of reformatting information that exists in the data base if the data base is complete.

Development of Fully Proceduralized Troubleshooting Aids requires considerable technical expertise in applying troubleshooting strategy and in knowledge about the particular equipment system involved. Equipment functions must be identified, function failures described, equipment failure modes determined and Action Trees prepared in accordance with a specified troubleshooting strategy. The Action Trees are then put into the specified format, supplemented by locator illustrations, to make up the Fully Proceduralized Troubleshooting Aids.

After draft copies of the JPAs have been completed, two activities remain in the process: Review and Verification, and Production and Delivery. These activities are not covered in detail in this handbook.

Verification is the process by which technical data are tested and proved (by Air Force personnel under Air Force jurisdiction) to be adequate for operation and maintenance of the subject hardware. The terms, conditions and schedule will be developed as deemed necessary by the procuring agency.

The Production and Delivery activity includes conversion of verified, translated final draft JPA into camera-ready copy or any other form specified. It also includes packaging and shipping.

Considerations for updating the various JPA products are also noted at appropriate points within the process descriptions. The data collection forms and techniques allow retrieval of all task and hardware-related information required for JPA updating, whether manual or electronic data processing (EDP) indexing is used. JPAs differ from conventional technical data in that most JPA updating requirements are derived from changes in tasks. Hardware changes that have no task-related implications will require no modifications to JPAs.

As can be seen from this brief summary, development of fully proceduralized JPAs places relatively greater emphasis on technical know-how and relatively less emphasis on writing than does development of conventional technical orders. The fully proceduralized JPAs are much more specific and detailed in telling the maintenance technician not only what to do but how to do it.

An Experimental Comparison of Procedural and Conventional Electronic Troubleshooting (Ref. 15)

This study is one of a series of six studies involving variables in the design and use of job performance aids for electronic maintenance. Variables examined to date have been subject aptitude, performance aid level of detail, performance aid format, performance aid method of presentation and task structure.

This study concerns itself with the variable of task structure. Two types of electronics maintenance task structure were compared: tasks involving decision (conventional) troubleshooting aids and tasks involving fully proceduralized troubleshooting.

The study found that the within-stage troubleshooting performance of experienced technicians, using conventional job performance aids, was not substantially superior to that of the inexperienced high school students who used fully proceduralized performance aids for troubleshooting. The technicians participating in the study had received many months of training and many years of on-job experience. The high school students had received only a few hours of training with their special performance aids and had no experience at all.

Two groups of subjects solved the same set of 13 troubleshooting and repair problems in seven solid-state circuit modules which contained up to five stages each. Both groups used the same hand tools and test equipment. One group was composed of 41 Air Force 5 and 7 level technicians who normally maintain such equipment as part of their jobs. The technicians used the same troubleshooting techniques they ordinarily used on their jobs, and they were provided with a conventional technical order-like performance aid to support the task. The other group was composed of 20 high school students with no prior training or experience in electronics. Their training for this study consisted of a special 12-hour course (compared to several months for the technicians) and they used a specially developed performance aid which told them which check to make, based on the outcome of previous checks. In terms of the speed with which they worked or the frequency with which they were able to effect repairs on the modules, there were no substantial differences between the two groups. But the difference in training time and, therefore, cost of training between the two groups is so great as to suggest the possibility that job-relevant training and proceduralization of the task can introduce substantial savings, even after the cost of developing the special performance aids required by proceduralized troubleshooting is subtracted.

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SIMM - Symbolic Integrated Maintenance Manuals (Refs. 9, 48 & 50)

SIMM is a manual concept designed to reduce the complexity of technical information. It contains all the information found in the conventional technical manual, but presents it in a graphic form that is easier to understand and also uses some color shading for rapid identification of functional and physical entities. SIMM pages vary in size (up to a maximum of 15 x 35 inches for multiple page manuals) but usually are larger than conventional manual pages. Normally, they are in loose-leaf form and are usually held together by ring binders.

The main features of the SIMM technique are the blocked schematics, precise access blocked diagrams, blocked text, and the maintenance dependency charts (MDC). Both the blocked schematics and the precise access blocked diagrams have facing pages of blocked text.

Blocked Schematic - By definition, a blocked schematic is a schematic diagram laid out in block form. It distinguishes the functions and physical aspects of the hardware by using shaded areas of blue and shaded areas of gray. The darkest blue-shaded areas denote the lowest functional features of a circuit (lowest definable basic circuit, filter, converter, amplifier, relay contact, meter, coils, switches, etc.) and the gray-shaded areas denote the hardware (chassis, drawer, module, etc.). Each successive higher level functional feature of circuits is shown in successive lighter shades of blue.

The blocked schematic provides the most detailed level of coverage. The precise access block diagram is the next higher level of system information.

Precise Access Block Diagram - The precise access block diagram shows all the functional entities within a unit, signal flow within the unit, and all cabling and wiring within the unit. Each functional entity, shown by symbols, is identified by the circuit-identifier code and blue-shading used on the blocked schematic diagram. Gray shading, showing the physical location of the functional entities, is also used on the precise access block diagram.

Blocked Text - Blocked text is presented on a page facing the blocked schematic. The arrangement of the blocked text is identical to that of the blocked schematic diagram except that terse text of high information content per word germane to the functional entity being described is substituted for the circuit elements in the respective blue-shaded area. Paragraph numbers, reference to illustration, complete sentence structure, and formal grammatical rules are not necessary to impart all needed information.

Maintenance Dependency Chart (MDC) - One of the most important features of the SIMM publication is its troubleshooting tool, the maintenance dependency chart. In addition to front panel marked indicators displayed across the top of the page, the chart illustrates the various assemblies, functional entities, or circuit elements through which a signal passes. It also includes the chassis or cabinet location of the items displayed across the top of the page. Each horizontal line results in an action such as a lamp lighting, an antenna

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rotating, a meter indicating or an indication of signal availability, heretofore referred to as an event. Each horizontal line (event line) is a representation of the circuit that develops the event on the line. The maintenance dependency chart has the unique advantage of permitting the simple display, in a limited space, of many events and their relationships.

This method of fault isolation is based on a positive approach. It is an analysis of circuitry to see that the things that should have happened did happen. Thus the event, if normal, is either readily observable, or its signal availability can be measured. If either the action or signal availability is not present, the functional entities, circuit elements, or circuits upon which the event is dependent can be readily determined.

Other features, not necessarily unique to SIMM, are:

1. A parts location diagram using a grid over-printed on an illustration to simplify parts location.
2. Maintenance data, etc.

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PRODUCTION PHASE  
ABSTRACTS

This segment groups all of the functions required to convert draft engineering writing into a manual or technical order by printing or converting to a microform. These activities include typing, illustration, layout, formatting, production of negatives, packaging and shipping.

Industry activity in the production segment pertains to the mechanization of production tasks. Practically all effort is directed toward reduction of manhours required to perform the tasks necessary to produce hardcopy manuals or microfilm. At the present time the market is flooded with devices and equipment that in varying degrees automate production tasks.

Figure 1 is a sampling of equipment in various price brackets that are currently available. No attempt was made to select a set of hardware to do a particular job. No criteria was established, as this would be a complete study in itself. It is sufficient to say that all equipment viewed would reduce manpower requirements. Other factors that would have to be considered would be cost versus annual production, programs to amortize initial investment, particular equipment advantages and disadvantages, etc.

In addition to the equipment comparisons listed in Figure 1, two production systems were reviewed in detail: the Vought Videographic System and the F-15 Technical Publications Program. Abstracts of the systems follow.

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FIGURE 1  
PHOTOTYPESETTING SYSTEMS ANALYSIS

MACHINE SPECIFICATIONS	SINGER BUSINESS MACHINES				VARITYPER		HARRIS INTERTYPE CORP.		PHOTOM INC.	
	PHOTOMIX				A.M.		PHOTOTRONIC		7000	7700
	8100	8200	8400		744	747	1200	CRT	CRT	
FORM OF INPUT	Paper Tape	Paper Tape	Paper Tape		Paper Tape	Paper Tape	Paper Tape	Magnetic Tape	Paper Tape On Line	Magnetic Tape
ACCEPTS UNJUSTIFIED TAPE	Yes	Yes	Yes		Yes	Yes	No	No	No	No
JUSTIFICATION: 1 - HYPHENLESS; 2 - DISCRETIONARY; 3 - LOGIC	1-2-3	1-2-3	1-2-3		1-2-3	1-2-3	--	--	--	--
SPECIAL KEYBOARD REQUIRED	No	No	No		No	No	Yes	No	--	Yes
TYPE OF TAPE READER	Photo Electric	Photo Electric	Photo Electric		Electro Mechanical	Electro Mechanical	Electro Mechanical	Computer Mag Tape	Magnetic Tape	Photo-Ele. or Mag Tape
READER SPEED (CPS.)	300	300	300		50	50	60	3000	500/30,000	24"/Sec.
FORM OF IMAGE MASTER	Font Seg.	Font Seg.	Font Seg.		Disc	Disc	Disc	Dig. Store	Film Strip	Dig. Store
TYPE FACE CAPACITY	4	4	4		4	3	10-15	Comp. Cap.	20-100	2
TOTAL CHARACTER CAPACITY	408	408	408		448	336	1200	256/8192	10-50K	210
CHARACTER SELECTION METHOD	Fibre Optics	Fibre Optics	Fibre Optics		Rotating Disc	Rotating Disc	Rotating Disc	Digital Store	Digital Store	Rotating Drum
CHARACTER EXPOSURE METHOD	Character Flash	Character Flash	Character Flash		Character Flash	Character Flash	Character Flash	CRT	Character Flash	CRT, and Lens
MAXIMUM LINE LENGTH (PICAS)	47	47	47		20 1/2-33	36 to 45	51	100	50 or 70	45
TYPE SIZE RANGE (POINTS)	5-18	6-18	6-36		5-18	5-18	5-72	1/2 to 144	4-72	6-36
TYPE SIZE CHANGE TECHNIQUE	Lens Turret	Lens Turret	Lens Turret		Lens	Lens	200M Lens	Electronic	Lens Turret	Computer
AUTOMATIC SPACE INSERTION	Yes	Yes	Yes		Yes	Yes	Yes	Computer	Computer	No
KERNING CAPABILITY	No	No	No		Yes	Yes	Yes	Computer	Yes	Yes
APPROXIMATE BASE PRICE	24,500	26,500	30,000		14,000	20,000	65,000	325,000	70,000	185,000

VVS - Vought Videographics System (Refs. 6, 12 & 53)

The VVS is a real time text processing system that facilitates the entry, storage, modification and transmission of data. It is a combination of individual items of equipment utilizing a unique software program to integrate the best features of each equipment into an efficient data system.

The basic advantage offered by the system is the inherent capability of a computer to store, manipulate, transform, and output data at rates much faster and more efficiently than available by any other means, while at the same time performing a myriad of different operations related to the data output form. The system is also capable of performing many types of operations more reliably and consistently than either a human being or mechanical devices.

VVS is an on-line system composed of an input device, a central processing unit and an output device. The system is not unique because similar systems are available. However, the system offers unprecedented advantages in the software and design approach which will not be found in any other system currently available.

The system has been designed to recognize that technical manuals contain two basic types of data as follows:

- a. Data having a rigid format such as Illustrated Parts Breakdown group assembly parts lists.
- b. Data which must be formatted as required to permit generation in a manner which provides effective accomplishment of intended purpose.

To accommodate these requirements, the system has been designed to maximize automatic system formatting and composition of rigid format data with minimum terminal control requirements.

A keyboard terminal equipped with a tape cassette is used as the input device, since the primary purpose of the system is to process the written word in the form of text or tabular data.

The number of machine instructions which the operator must input via the terminal has been held to a minimum. This has been accomplished, where possible, by having a single input instruction accomplish several computer operations via the software routines. Normal typewriter operations, such as a carriage return, are utilized to generate command codes where practical.

All general format and copy placement parameters are resident within the software routines; they are not defined by individual input instructions. This includes the placement of illustrations and tabular data in relationship to text. In effect, total page makeup, with the exception of variables, is controlled by the software - not the operator.

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Simple mnemonic commands are used at the terminal. The mnemonic commands are converted to more detailed machine instructions during data processing by the machine itself. In the current system configuration a total of approximately 60 commands are required to define all composition requirements for:

- a. General page format and copy placement parameters.
- b. All heading, text and tabular typefaces.
- c. All leading requirements.
- d. All indenture requirements.
- e. Illustration sizes and captions.
- f. Tabular data format.
- g. Superscripts and subscripts.
- h. Miscellaneous requirements such as: fill with space, fill with leader dots, obliquing, underlining, etc.

The VVS has been designed to avoid the usage of tab racks or tab commands for the input of any data, including tabular data. As a result, all input is free-form typing increasing the rate at which an operator can introduce data into the system.

The input terminal utilized is equipped with a tape cassette unit. This permits the operator to continue to do useful work although the CPU is inoperative. The tape cassette provides the capability and permits data to be transmitted to the computer when desired. Also, data can be recalled from the computer and stored on tape cassette tape cartridges.

The VVS is functionally divided into two segments and utilizes two CPU's and two different basic software packages. These segments may be defined as the system text editing and processing segment and the data formatting and composition segment.

The two segments of the system are, in effect, tied together by a pre-processor program. The text editing and processing segment outputs a data tape. The data tape is in turn processed by a pre-processor program to generate an amplified and reformatted data tape. This data tape is inputted to the data formatting and composition segment of the system to output a CRT composer compatible formatted drive tape. The drive tape is used to drive the CRT composer output device to generate final composed CRT copy.

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USAF F-15 Fighter System Technical Publication Program (Ref. 49)

This is a paper presented by Major David Teal at the NSIA Publications Panel Meeting in Houston, Texas, April 23-26, 1973. It covers the F-15 Publications Program from inception to the present, with a look into the future.

It is a large program requiring over 1000 individual technical publications to support the weapon system. The major breakdown is as follows:

- Aircraft, approx. 100 manuals
- Aircraft System, approx. 400 manuals
- AGE, approx. 400 manuals
- Engine and Engine Accessories, approx. 45 manuals
- Engine AGE, approx. 100 manuals
- Misc., Training and Tactical Systems, approx. 50 manuals

The F-15 Publications Program, although a new program, is essentially a traditional type publications program. Some innovations are incorporated, however, which related together improve the total publications program. These innovations are summarized as follows:

1. Management Emphasis - The major unique factor is the attention given to this aspect of the F-15 program. Normally, a single Data Manager handles all data, including manuals. The Program Director recognized the importance of publications in 1969 and organized a separate branch which could be manned with the proper number of experienced people to deliver adequate and accurate data to the using command. Once this was accomplished, the branch could maintain the necessary control and visibility needed. For example, the Data Manager usually had to delegate the evaluation of proposals for procurement of CFAE/CFE manuals to AFLC AMAs because of his lack of time and expertise. These manuals cost millions of dollars and deserve the attention and integration capabilities of a SPO. The F-15 maintained this responsibility and has kept CFAE/CFE manuals under tight control, as evidenced by the fact that funds obligated for manuals are well under amounts needed for past programs at this point in the life cycle. By being able to closely evaluate ECPs, the branch has been able to reduce proposed T.O. costs by factors over 50% by recognizing duplication, unneeded effort, misinterpretations, and most cost-effective alternatives.
2. Development Program Manuals (DPMs) - These manuals enable technical data to be developed concurrently with the hardware at no additional cost. These manuals get technical writers on board at an early date. The technical writer's efforts reduce the need for redundant procedural data from engineering, manufacturing, and test organizations as all can use the DPMs. Since the DPMs can be transitioned into T.O.'s during production, their use in R&D helps to improve the quality of the data. DPMs reduce the need for special material to conduct Type I training. This eliminates data items from the CDRL. Operations and maintenance data is available in AF DT&E much earlier than normal.

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3. Technical Order Standardization Board (TOSB) - This board was formed at the very beginning of full scale development to insure using, supporting, and implementing command coordination on all major decisions concerning publications. This board has met at least quarterly since early 1970 to act on specification interpretations and deviations as well as approving several verification plans.
4. Specification Interpretation Conferences - Military specifications are often general in nature to cover aircraft, missiles, spacecraft, electronics; etc. These specifications sometimes offer alternative approaches to meet the final requirement. To tailor these specifications to the F-15 program and select the appropriate alternative listed, a specification interpretation program was initiated. This activity covered a two year period and involved over 40 specifications. The TOSB made the final determination on interpretations which are recorded in specification interpretation documents (SIDs) which become an integral part of the specification.
5. Verification - The F-15 program will verify four to five times as many manuals in one-half the time normally allocated for this effort. This objective was established to increase the accuracy and adequacy of manuals and to enable delivery by the time TAC gets its last aircraft in the first squadron. To achieve this ambitious objective, two major management decisions were made. One was to put the verification effort under the responsibility of a full time maintenance officer. Normally, verification is managed as a part of the Personnel Subsystems Test and Evaluation (PSTE). A Human Engineer is usually in charge of this effort and lacks the maintenance experience needed as well as adequate time and staffing. The Verification Team Manager (VTM) reports directly to the JTF Director, has a staff of five NCOs, chairs the technical publications review board which acts on change recommendations, and has 21 TAC personnel identified with verification as their primary duty. The second management decision was to schedule completion of verification on each manual in time to meet the delivery date for verified manuals to TAC.

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**USE PHASE  
ABSTRACTS**

This segment groups the user activities of technical order maintenance, filing, controlling configuration, distribution, etc. It includes all of the types of media display (hardcopy manuals, microforms), display equipment, automatic maintenance data equipment, automatic test equipment, etc.

In this area the government services (Army, Navy, Air Force, and Marines) have concentrated their efforts. They believe that here the opportunity is for the greatest payoff in reduction in life cycle costs of weapon systems. It is also in this area the biggest problems exist. For example, government studies have shown that 30% of a maintenance man's time is spent searching for data; changed equipment is in the field long before the associated technical data is available; 35% of the items of equipment removed for maintenance are found to be in good working order at subsequent shop examination.

The abstracts contained in this section consist of studies, hardware systems, and activities conducted by the government in an attempt to solve a particular technical manual problem.

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WSMAC - Weapon System Maintenance Action Center (Refs. 48 & 54)

The WSMAC system of automated technical data storage, retrieval, and presentation, developed by McDonnell Douglas Corporation, utilizes microfilm with a reader-printer to view and print, as required, maintenance data necessary in the analysis and repair of an airborne weapon system. It utilizes off-the-shelf commercial equipment which is slightly modified to suit the purposes of the WSMAC system.

The maintenance data consists of conventional organizational level maintenance data which has been re-arranged and re-indexed by systems, with logic tree trouble analysis diagrams added. This data is then microfilmed and coded utilizing the Work Unit Code (WUC) as the first two digits of a binary code which provides a means for immediate access, on an automated search and retrieval mode, of the required information. The WSMAC documentation includes both the logic tree trouble analysis for fault isolation and the detailed procedures required for completion of the defined maintenance task for the complete weapons system. Maintenance data required by system, sub-system, component, maintenance procedure, part number, or malfunction can then be viewed and printed as required.

The printing of selected information permits the maintenance personnel to have only the required data available at the work site without the necessity of carrying a large maintenance manual with them. Data on the film is updated and updated film cartridges are sent to the using activity and the outdated film cartridges are discarded. This greatly assists in maintaining data integrity and ensures that only the latest corrected data is available to the using activity. The using activity no longer has a responsibility to make changes to the data (presented in the film cartridges).

The WSMAC information represents a rearrangement of technical manual material for immediate and automatic retrieval. A software effort of eliminating as much technical jargon as possible, maximizing the use of logic tree fault isolation methods, eliminating cross-referencing between publications, etc., has been made for organizational and intermediate level publication data.

The key to WSMAC is the indexing. The indices to the WSMAC data bank are in many respects analogous to the programs prepared to extract data from the 3-M system. Immediate access allows the machine to file specific data or data packages to be available upon request. A goal of WSMAC is to eliminate the cross-referencing inherent with publications and provide all data as if it were from a common source.

Entry into the data bank is through a "symptoms index." A code is shown with that symptom which is really an immediate access address or program for all necessary information that may be required to take corrective action for that symptom. The maintenance action printouts are quite comprehensive. The attempt is to provide a complete data package for the unscheduled maintenance task of determining the cause and repairing the discrepancy.

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In brief, WSMAC involves a new concept towards presenting and providing maintenance information to the mechanic. It is a complete data package designed to replace existing publications for use at organizational and intermediate maintenance levels.

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MICROMS - Micro Information Concerning the Repair and Operation of Missile Systems (Ref. 32)

This concept addresses itself to the handling, storage, and retrieval of technical data. It deals with media, methods, and equipment.

The documentation has evolved through "MICROMS" dated April 1968, "Guidelines for Converting Maintenance Data to Microfiche" dated April 1968, and "Microfiche vs Printed Manuals" dated January 1969. The latest title is "Microfiche in Missile Maintenance" dated April 1970.

Although the system is supposed to cover all micro information systems, the Army has selected microfiche as the microform to use. Therefore, the documentation seems to justify that decision. The book covers the advantages and disadvantages of other microforms. The major information presented deals with the use of presentation and equipment required. It also presents comparative costs for fiche, printed manuals, distribution, and storage.

As a final part of the discussion, guidelines are presented for converting maintenance data to microfiche.

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RAPIDS - Rapid Automated Problem Identification Data System (Refs. 41 & 42)

RAPIDS consists of a data bank of technical information for accomplishing unscheduled maintenance. The information is stored on cartridge contained 16mm film, each cartridge capable of storing approximately 2500 documents with expansion possible to 5000 documents. Each document is coded and can be automatically, semi-automatically or manually retrieved and viewed on the RAPIDS Data Retrieval Station.

A printer is incorporated to provide copies of the selected documents. Due to its high capacity for data storage, redundancy is not a problem; therefore, presentation of complete, all-inclusive data for a given task is made without cross reference to other data. This eliminates the necessity for a complex coding system for data retrieval.

RAPIDS procedures present a complete operation that accomplishes all unscheduled maintenance, starting with malfunction verification, fault isolation, maintenance actions, post maintenance checks, and maintenance reporting. RAPIDS is essentially a method of presenting maintenance data in a detailed logic-flow step-by-step checklist form, stating what to do and how to do it.

Troubleshooting data is primarily based on fault symptoms experienced during actual design, development, testing, and operational use of the weapon system. The procedures are the results of contractor maintenance experience prior to weapon system delivery and updated during military operational use. Most operational, mechanical and avionics malfunctions (75% according to statistics) will have occurred prior to delivery of the weapon system to the user. Therefore, RAPIDS covers most expected malfunctions, with their associated symptoms, and the maintenance procedures which have been successfully used and proven by contractor maintenance technicians. The system minimizes the problems related to unwieldy, voluminous maintenance data, the shortage of trained and experienced maintenance personnel, and the high rate of unnecessary removal of properly functioning components.

A malfunction in one system sometimes is caused by a fault in another system; RAPIDS fault isolation procedures consider this and present complete integrated data for fault isolation in order of probability and ease of accomplishment as determined by reliability data, historical data and military record systems data. Non-relevant information which delays the maintenance action does not appear. A technician can follow a RAPIDS procedure beyond the system(s) in which he is trained or rated, enabling him to check interfaces. The fault can be isolated without exhaustive checks on each system.

RAPIDS is an effective aid to maintenance management. In addition to complete technical data for unscheduled maintenance, it provides logistical data (i.e., personnel and skill level, support equipment required, probable material requirements, time to accomplish the task and maintenance reporting). The maintenance reporting aspect of this system can be tailored to existing military record systems (i.e., Navy Maintenance and Materiel Management (3M), Air Force Manual 66-1 and the Army Equipment Record System, TAERS).

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RAPIDS Data Retrieval Station Technical Description

The primary function of the RAPIDS Data Retrieval Station is to provide quick access to, and printout of, job-oriented maintenance data. The main features of the Data Retrieval Station are:

- Militarized unit
- Easily maintainable
- High reliability
- Minimum logistical requirements
- Simple operation
- Three distinct modes of operation
- Fast retrieval of data (10 seconds)
- Fast print (6 seconds)
- Variable length printout
- Immediately usable copy
- Front loading
- Bi-directional search of documents
- Auto/manual film threading
- Automatic self test
- Capable of accepting all known Mil Spec microfilm
- Operates on single phase, 115-volt power.

NOTE: This equipment is presently being used by Attack Squadron VA-42 at the Naval Air Station, Oceana, Virginia.

DESCRIPTIONGeneral

The RAPIDS Data Retrieval Station (designed to Grumman DCS-GC1A-1000, Rev. A) is a self-contained machine capable of displaying and making enlarged copies of 16mm microfilmed data. It is also capable of automatic retrieval of the data, automatic display, and/or automatic printing of the desired frame(s).

Display of the microfilm data is on a 10 x 11½ inch viewing screen, and the printout is approximately 8½ x 11 inches. The machine can print out single 8½ x 11 sheets or longer, in multiples of 11 inches.

Configuration

The RAPIDS Data Retrieval Station is housed in a single cabinet encompassing two major assemblies. The upper assembly is a Reader/Printer, and the lower assembly is the Keyboard/Electronics Control Unit. Both of these assemblies are mounted on slides for ease of refilling printing paper, the print activator and performing maintenance or inspections.

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Reader/Printer Assembly

The Reader/Printer Assembly contains all the optics, film transport mechanism, print processing, film display, film code detection system, and such controls as necessary for manual control of film reading and printing. The Reader/Printer Assembly is capable of operating in the manual mode, with the Keyboard/Electronics Control Assembly removed.

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PCMI - Photochromic Micro Image (Ref. 34)

This is a report by the National Cash Register Company on the technology and associated hardware necessary to produce, store and read micro-images.

The report has several purposes. It first discusses the historical development of microphotography since its invention in the fall of 1839. It then defines the basic PCMI process and its current capabilities. Next, extension of PCMI's functional and system characteristics are given to provide a foundation for the subsequent discussion of potential applications. Classification of broad PCMI application areas are discussed first to develop an overall perspective before specific areas of information processing are covered. Each application area is treated with respect to its historical development, current problems and state-of-the-art, and future needs. Wherever possible, suggestions are given for potential uses of micro-images.

Key factors in the success of the PCMI process are the following capabilities: a) inspection and error-correction at the micro-image level; b) high-resolution contact printing of micro-images on a mass production basis; and c) simple, effective retrieval and utilization of micro-images by means of specially designed viewers. A basic PCMI system, consisting of a camera-recorder, automatic contact printer, and a micro-image viewer, has been completed and is operational. Development studies are underway with this equipment to accumulate data for system application studies.

Major application areas for PCMI techniques are information storage, retrieval and dissemination, microform publishing, specialized library uses, and computer generated microform. The requirements for these applications are reviewed with some detail.

At the present time, the greatest single hardware area requiring more research and development is for micro-image viewers. It is emphasized how important both the economics and quality of viewers are to user acceptance of microforms. This will be especially true in the case of high reduction micro-images where the potential user will understandably be more apprehensive about the practicality of their use at first. Desirable viewer developments are: more effective ways to employ tungsten, instead of high-energy, light sources; hardcopy output capability; microfilm output capability; automated transparency positioning table; and more compact, lower cost units. Particularly valuable from the applications viewpoint is the eventual development of a very low-cost (less than \$100), good optical quality, portable viewer for home, school, and general use. Successful development of such a viewer is the most important single development still missing in PCMI.

The invention of the PCMI process by NCR scientists, and its current availability for broad application, should prove to be a most timely and important contribution to the state-of-the-art of information processing since new techniques and imaginative approaches to better information handling are urgently needed. The intrinsic properties of PCMI which appear to be attractive for this purpose are:

- Adaptability to unit media-type information handling
- Fast, random access retrieval
- Extension to very large capacity storage

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- Economical file dissemination
- Economical file decentralization
- On-demand output capability

The characteristics which make PCMI technology unique in its field can be summarized as follows:

- Photochromic coatings provide very high resolution with no grain.
- Photochromic coatings provide immediate visibility of the image upon exposure.
- Photochromic coatings permit both erasing and rewriting functions. This permits the processes of editing, updating, inspection, and error correction to be incorporated into PCMI systems.
- The PCMI process incorporates the ability to effect a bulk-transfer read-out of micro-images with over a 200-to-1 reduction ratio by contact printing, and can accomplish this on a mass production basis.
- Use of high-resolution silver halide emulsions provides both permanency for the storage of micro-images and economical dissemination of duplicates.
- The very high storage density of 100-to-1 to 200-to-1 micro-images offers the possibility of using some form of "manual retrieval" techniques for many applications. This eliminates the normal requirement in systems of this size for expensive and complex random access hardware.

Throughout the report, extensive literature references have been cited to provide a starting place for further studies, since another purpose of the report is to stimulate such work.

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Microform Compatible Technical Manuals; Naval Air Systems Command -  
Aeronautical Requirement (Refs. 36, 37, 38, 39, 40 & 43)

This is a series of four new Navy technical manual requirement specifications. They were developed to make all new Navy air technical manuals acceptable for microforming (microfiche, microfilm).

The four new aeronautical requirements are: General Style and Format, Preparation of - AR-75; Aircraft, Equipment, and Component Maintenance, Preparation of - AR-76; Illustrated Parts Breakdown, Preparation of - AR-78; 16mm Microfilm of Technical Manuals: Requirements for AR-84. These Navy requirements permit changes to traditional methods of manual production to accommodate microform data presentation.

They also permit the use of contractor mechanization of manual production methods by use of computer driven phototypesetting equipment, electrostatic, impact or film setting printing devices.

The detail changes to the requirements are made to facilitate the use of microform display of data for all levels of maintenance from organizational to depot.

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A Study - Determination of Tech. Manual Utilization and Adequacy (Ref. 13)

This report, dated 30 July 1962, presents the results of a research effort conducted on the frequency of use and adequacy of technical manuals at operational ballistic missile sites. The report consists of a literature survey including bibliography listings and annotations; a state-of-the-art summary based on the literature survey; and preliminary field trips, plans, and recommendations for future research in the specific area of technical manuals.

The study was conducted under the cognizance of the Ground Systems Department of the Systems Research and Planning Division of Aerospace Corporation. R. W. Cunningham and E. H. Edwards defined and coordinated the general tasks required in support of a personnel subsystems applied research activity.

The study was accomplished and the report prepared by W. C. Urlovic of the Cost Department, System Analysis and Evaluation Subdivision.

The goal of the complete program is a set of specific recommendations for changes in contents, format, organization, etc. of technical manuals.

The study was initiated with the explicit assumption that the preparation of original and revised technical manuals was costly. Preliminary evaluation indicates that technical manual contract costs are minor in comparison with the total cost impact of the use of manuals, total system availability, and resulting missile system effectiveness. Manual contract costs alone are less than 2 percent of hardware contract costs, on the average.

The literature survey has shown that no objective measured data exist on frequency of technical manual use. A poll of 2300 personnel indicated many of the problems to be evaluated but should be considered as a collection of opinions to be evaluated by test data. Specific Data Collection Forms have been designed for use in interviewing contractor and Air Force personnel, and in measuring usage. It was recommended that an agency possessing capabilities in various disciplines be contracted to complete this Plan as detailed herein. This team should include human factors specialists, social psychologists, technical manual specialists, design engineers, and field-experienced operational personnel.

A study of recently-developed techniques and devices to supplement or replace technical manuals hold more promise in the long run for major improvements needed than do evolutionary changes in manuals or better quality control of manual preparation. It is concluded that the manual or its equivalent should be designed to meet the particular maintenance and operating needs to minimize total system costs.

The study conclusions are listed as follows:

1. No objective measurements of T.O. usage exist in the literature.
2. Contract costs for T.O.'s are probably less than 2 percent of equipment contract dollars, but the usefulness of T.O.'s may in large measure determine the missile maintainability index (downtime) and system total availability.

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3. Checklists are useful in evaluating format and presentation of T.O.'s but weighted index numbers derived from checklist data are of more questionable value. Simple methods of judging T.O. technical accuracy do not exist.
4. Contractors do not have available detailed descriptions of what circuits and technical knowledge various skill levels and specialty codes may be assumed to know. The Navy is reported to have such a guideline in process.
5. No reports available deal with comparison of reader needs for different types of systems or with expected trends in reader needs because of changing maintenance concepts and plans.
6. The literature is overwhelmingly in agreement that serious problems exist in the design, use, and revisions of technical manuals. The quotations from Air Force technicians are impressively alike in the detailed objections and suggestions, but some of the poll data are confusing in the varied weights placed by these personnel on various deficiencies.
7. Improvements to the T.O.'s themselves may contribute substantially to present effectiveness, but even greater changes may be possible with the application of new automatic devices or other new techniques.

An Industry Study of the Use of Technical Orders in Support of Flight Line Maintenance (Ref. 1)

This report was prepared by the "National Security Industrial Association" Logistics Management Advisory Committee, Technical Publications Panel and published 1 June 1972. It is the latest technical order study in existence at the present time. The conclusions and the study team recommendations are as follows:

- The present technical order system does not get the flight line maintenance data in the hands of the user in a direct or timely method.

Recommended providing data on 16mm microfilm with reader-printers being placed in maintenance vans or in the flight-line maintenance office.

- The kind and quality of data provided doesn't always support the maintenance plan.

The total logistics support system - manuals, training, spares, test equipment and all maintenance levels - must be examined from a data viewpoint.

- The preparation of T.O.'s to Specific T.O. specifications many times provides data that doesn't support the way maintenance is accomplished.

Recommend that disciplines, procedures, and practices be established to enable technical orders to be prepared to contract end item specifications. This study to include an analysis of both the format and content of technical orders.

- The ultimate real-time data objective requested by the user must be provided.

Recommend that contractors be encouraged and funded to computerize the production of T.O.'s and to develop data storage banks.

- Maintenance studies and reports show a "shot-gun" type approach to troubleshooting, causing unnecessary removal of equipment, etc.

Recommend particular attention be given to the procurement of more effective troubleshooting information.

- Since communications is one of the major management problems, it is felt that objectives must be defined, plans outlined, and programs detailed.

- Recommend an Air Force/Industry seminar to be held before 1974 to develop a data roadmap and communicate the role technical data will play in the 1980's.

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SUMMARY ASSESSMENT AS A RESULT OF PHASE I STUDY EFFORT

In the 52-year history of the technical data business, very little change has taken place. Only the volume has grown as the complexity of equipment has increased. A pictorial representation of the T.O. requirements by representative aircraft is shown in Figures 2A and 2B. The demands for additional data have always lagged behind the engineering or hardware improvements, and any improvement on additional supply of data was a result of an intolerable or dangerous hardware situation.

As the volume of data has grown and the complexity of weapon systems increased, the maintenance man's dependency on the data has also increased. The deficiencies in the data system, far from being solved, have only been magnified and amplified.

The problems can be very simply identified as:

- I - Total Cost of Data
- II - Total Volume of Data Required
- III - Data Information and Presentation Deficiencies

The problems identified above are deceptively simple but are comprised of a myriad of interrelated sub-problems. A representative listing is as follows.

I. TOTAL COST OF DATA

- Contract Administrative Costs
- Manpower - Technical Writing
- Manpower - Production
- Printing, Storage, Handling Costs
- Restrictive Specification Requirements

II. TOTAL VOLUME OF DATA REQUIRED

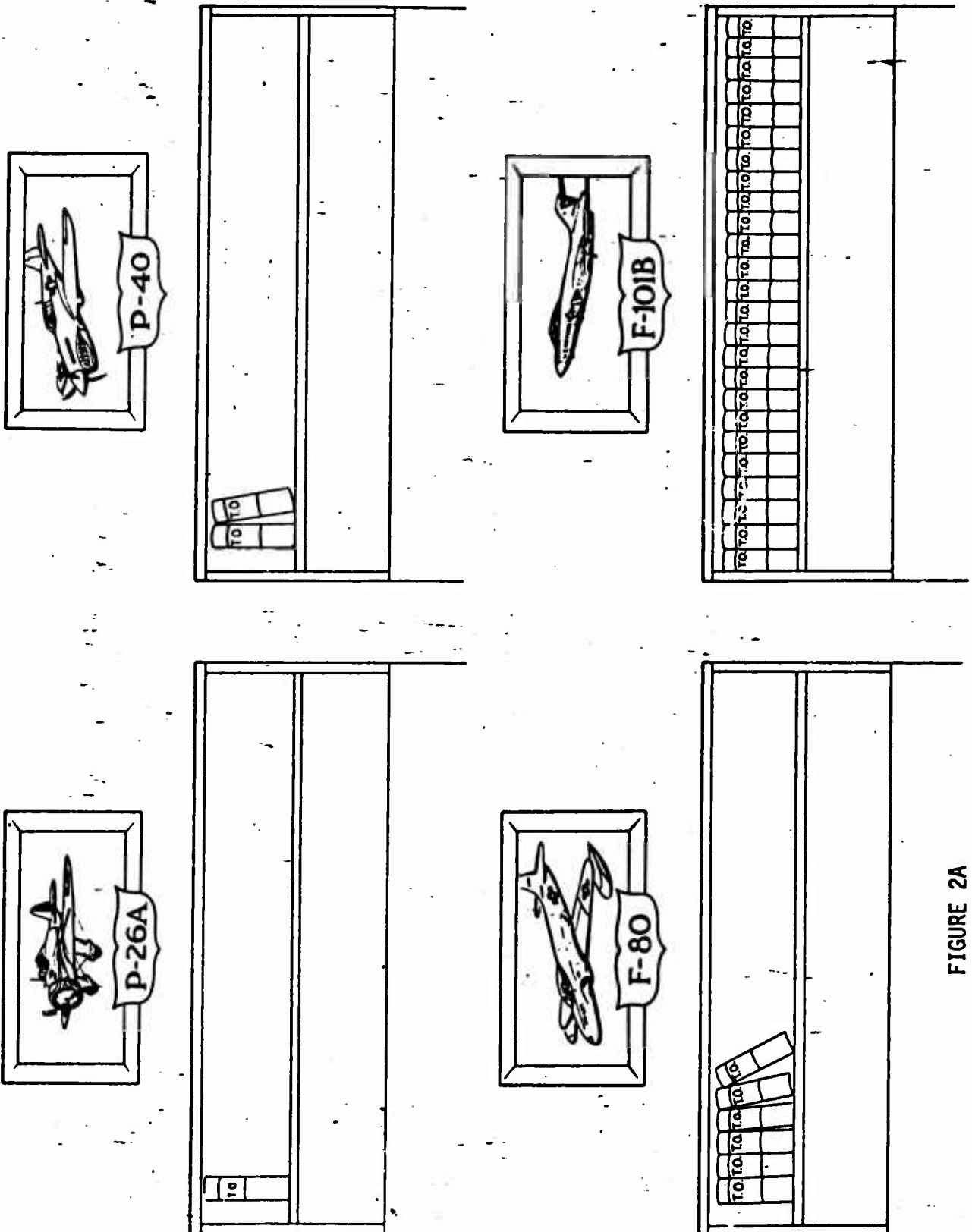
- Physical Data Storage and Storage Facilities
- Retrieval of Information
- Physical Handling and Processing
- Timely Processing of Changes

III. DATA INFORMATION AND PRESENTATION DEFICIENCIES

- Troubleshooting Data is Stereotyped
- Contains Diagnostic Deficiencies
- Not Specific to Situation
- Excessive Cross-Reference Requirements
- Does Not do the Job the Data was Intended to Do
- Permits Erroneous Removal and Replacement of Good Hardware
- Requires Highly Skilled Maintenance Personnel to Follow Instructions
- Manuals Bulky and Difficult to Handle

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**FIGURE 2A**

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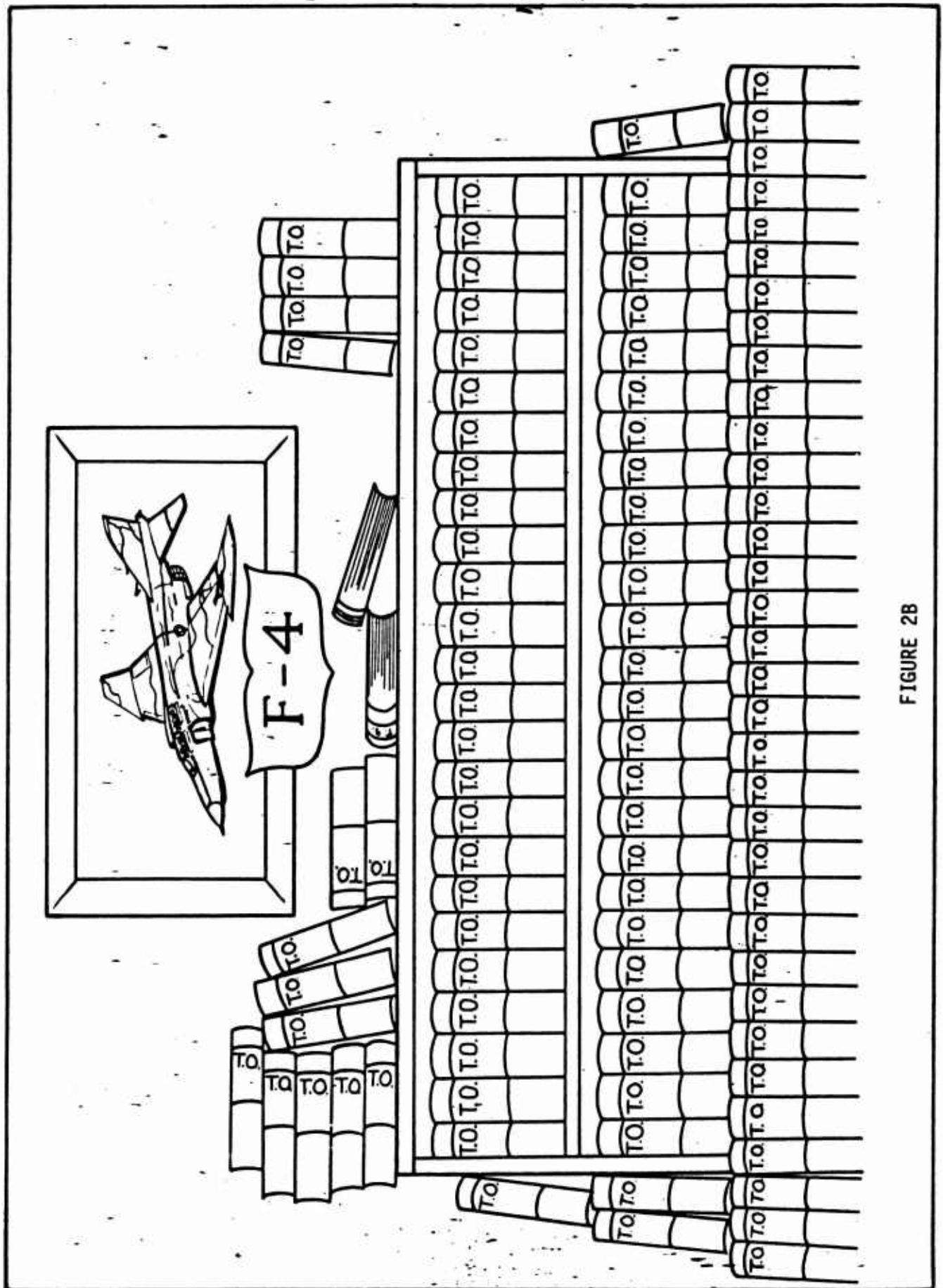


FIGURE 2B

As early as 1966, Col. E. G. Triner, in a speech made to the Society of Technical Writers and Publishers, presented the Air Force viewpoint that "it should be clearly understood that the existing technical order system is performing a needed function, it must be recognized that we are rapidly approaching the useful limit of our existing method of transmitting technical information.

"Notwithstanding major technological advances in high-speed communications, evidence abounds of the unacceptable delays experienced by the field in receiving the documentation needed to install, operate, and maintain changes to existing hardware. By Telestar, we can bounce information around the globe in micro-seconds. But it takes weeks, months and sometimes years to provide critically needed maintenance information to our troops.

"Of all the various phases of maintenance essential to the fielding of our complex systems, the most costly, from every aspect, is unquestionably what we term unscheduled maintenance. Anything which can be done to decrease the downtime of an operational system has significant dollar impact. In our sophisticated system, troubleshooting takes on an importance far beyond anything that we have seen in the recent past. Much of the troubleshooting data contained in our existing technical orders are stereotyped, are not specific to the situation, and require far too much time for implementation."

The conceptual problems noted in the Air Force viewpoint and repeated by the other services ten years ago can be reiterated today, and be just as valid today as they were then. In a sense, the services have left this area to the contractors and research centers such as Wright-Patterson AFB to develop, but they have an interest in exploring the innovations in the conceptual phase and have funded a number of test and evaluation programs. Even though several new concepts have been developed, as reported as abstracts in prior sections, the total implementation of any new concept has not taken place. They invariably proceed very cautiously in implementing any radically new system. In the past the Air Force has funded research and studies of the concept of Job Performance Aids and recently contracted with The Boeing Company at Wichita to convert a portion of its B-52 maintenance data to JPA format.

From the data reviewed, it is apparent that the government services have only a nominal interest in the mechanization of the production phase of technical data. Their interest would be the ultimate reduction of total data costs. Conversely, industry has a paramount interest in mechanization because of the savings in manpower, the better competitive position, and subsequently better profit position. With the tremendous smorgasbord array of equipment on the market today, any company can produce technical data more efficiently and possibly less costly by proper balance between amount of data produced and the cost of the equipment. Ultimately, these cost savings are passed on to the customer. This, then, is the interest of the government in the production phase.

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At the present time, the Services' prime interest is in the area of data handling, storage, retrieval, and use. The Army and the Navy have launched programs to convert hardcopy manuals to microforms. In the case of the Army, it is microfiche, and in the case of the Navy, it is roll film. The Air Force is microforming their depot technical data on cassettes. They have also conducted some tests and evaluations of hardcopy viewers for flight line maintenance. Although the Army and Navy have microformed their depot and some field maintenance data, it is surprising that after many years of tests, evaluations and proven worth of microform data, they have not, as yet, ventured into microforming flight line maintenance data. However, the potential for greatest benefits lies in this area.

The paper published by Aerospace Industries Association as a forecast of "Life in the Technical Manual Business in the Late 70's" is a good summation and forecast of the foreseeable accomplishments in the technical data field. It is provided as part of this section of the document to indicate the composite attitude on the part of the Technical Manual Industry for advancing the state-of-the-art.

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AIA Aerospace Technical Manual Requirements of the Late 1970's

Aerospace Industries Association (AIA) Service Publications Committee published this paper in April 1969 as a forecast of things to come in the world of technical data in the late 1970's. An attempt was made to project the type of weapons systems that would be in the DOD inventory in the next decade. This was not too difficult to project because most of the systems that may appear in the inventory are already under study or are in R&D phases. What is more difficult to project is what maintenance and support concepts would be utilized along with the knowledge and skill level required to operate and maintain the systems of the future.

The paper indicates the committee's study and evaluation of the most promising of the conceptual systems. The committee then superimposed several concepts of maintenance. For example:

1. System redundancy
2. On-board maintenance
3. Centralized maintenance
4. No maintenance.

From this base they attempted to forecast the content, format and display of the technical manual of the future.

The following is a list of conclusions reached by the AIA Publications Committee as a good possibility of the technical manual content, format, and method of use in the late 70's.

1. Weapons systems in the inventory of the late 70's will continue utilizing present concepts of maintenance and technical manual content and format.
2. New weapon systems introduced in the late 70's will incorporate with increasing frequency the concepts of "designed in maintenance aids" blended with manually performed corrective maintenance tasks.
3. The technician of the late 70's will come into the services with greater knowledge and increased skill levels. However, the increased complexity of the hardware will continue to require extensive service training supported by the "technical manual."
4. The effectiveness of automated equipment will probably relieve the technician of the major portion of the troubleshooting burden. However, when trouble occurs that is not automatically located, the technical manual must be immediately available and in a form for quickly providing the required maintenance information.
5. Automated maintenance concepts may not necessarily reduce the degree of technical content in the technical manual of the future. Detailed procedures and instructions will continue to be required to fault isolate malfunctions extending beyond the scope of automated detection.

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6. The content of the technical manual will remain essentially the same as today. Troubleshooting procedures will be presented in "logic tree" formats. Procedures will be presented in discrete steps with extensive use of illustrations economically feasible with the use of automated drafting equipment.
7. The format may take the form of partially or fully programmed presentation, based on the designed-in maintenance aids, operational availability, and the environment of the maintenance technician.
8. The physical package (display media) will be primarily in microform (roll, microfiche, etc.) assembled in various forms of automated storage and retrieval devices.
9. Standardized specifications will have been developed to provide direction as to the style of presentation desired for the required technical data. Major determining factors will be the complexity of the weapon system, the anticipated operational environment, the operational and maintenance concept, and the skill level of the user.

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APPENDICES

**APPENDIX A**  
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APPENDIX B  
PERSONNEL CONTACTED

Donald J. Anderson  
Westinghouse Electric Corporation  
Hunt Valley, Maryland 21030

Samuel Axler  
Supervisor, Equipment Specialist  
Army (Wecom Frankford Arsenal)  
AMSWE-MAF-W3420  
Philadelphia, Pennsylvania 19137

John Bean  
Hughes Aircraft Company  
Los Angeles, California

Don E. Bissell  
Publications Supervisor  
Sundstrand Aviation  
Rockford, Illinois 61101

William H. Brill  
Supervisor, Technical Publications  
Rockwell International Corporation  
Columbus Aircraft Division  
Columbus, Ohio 43216

Richard Rudd  
Chief, Technical Publication Div.  
Army Aviation Headquarters  
St. Louis, Missouri

Elihu Cohen  
Manager, UEP Technical Manuals  
General Electric, HMES  
Syracuse, New York 13201

Lt. Col. Charles D. Coleman, USAF  
Chief, Technical Publications,  
Data & Accounting Division  
Aeronautical Systems Division  
F-15 System Program Office  
ASD/YFCT  
Wright-Patterson AFB, Ohio 45433

Larry J. Garrett  
Advanced Publications  
LTV Aerospace Corporation  
Vought Systems Division  
Dallas, Texas 75222

William D. Goldstein  
Market Analyst  
IBM Corporation  
Gaithersburg, Maryland 20760

William Goodno  
RCA Corporation  
Burlington, Massachusetts

G. C. Grande  
Raytheon Company  
Burlington, Massachusetts

L. E. Gustavsen  
Manager, Technical Publications  
The deHavilland Aircraft of Canada,  
LTD  
Downsview, Ontario, Canada

James H. Hagel  
Acting Manager, Publications Dept.  
Martin Marietta Aerospace  
Orlando, Florida 32805

William Hand  
Westinghouse Electric Corporation  
Hunt Valley, Maryland 21030

Martin J. Johnson  
Manager, Publications Field Programs  
Raytheon Service Company  
Andover, Massachusetts 01810

Barney Kemp  
MICOM  
Redstone Arsenal  
Huntsville, Alabama

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Arthur C. Martin  
Manager, Technical Logistic Data  
Westinghouse Electric Corporation  
Hunt Valley, Maryland 21030

Howard G. Maxwell  
Research & Development Engineer  
Lockheed-Georgia Company  
Marietta, Georgia

Roy Post  
Supervisory Publications Specialist  
AMC Maintenance Support Center  
Letterkenny Army Depot  
Chambersburg, Pennsylvania 17201

George Rudd  
MICOM  
Redstone Arsenal  
Huntsville, Alabama

Phillip D. Ruth  
Manager, Support Management Dept.  
Collins Radio Company  
Cedar Rapids, Iowa

Edward A. Saxton  
Manager, Technical Manuals  
Philco-Ford WDL Division  
Palo Alto, California 94303

Major David J. Teal, USAF  
Chief, Technical Publications  
Management Branch  
Aeronautical Systems Division  
F-15 System Program Office  
ASD/YFCT  
Wright-Patterson AFB, Ohio 45433

Morris Underwood  
LTV Aerospace Corporation  
Vought Systems Division  
Dallas, Texas 75222

H. D. Vance  
Manager, Technical Publications  
McDonnell Douglas Electronics  
Company  
St. Charles, Missouri 63301

Frank Winship  
McDonnell Douglas Corporation  
St. Louis, Missouri

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APPENDIX C  
TECHNICAL MANUAL INDUSTRY PROFILE REPORT

This study is a compilation of pertinent questions submitted to 34 companies having technical publications organizations. An abstract of the replies follows.

Sixty-nine percent of all companies reported that some specifications are too trivial, while 21% of all companies stated that specifications hinder the capability of providing adequate data.

In preparing cost estimates, 51% of all companies reported that each different type of page is the level of detail employed.

The principal causes of any budget overruns appear to be the result of in-house problems of over 90% of the reporting companies. Problems include engineering redesign, schedule slippage, lack of proper controls, and delays in obtaining source data.

Eighty-seven percent of the companies have an active cost reduction program in the technical publications department.

Thirty-nine percent of the companies believe that the technical manuals department should provide to the company training department preliminary equipment manuals, theory manuals, and training equipment manuals, in lieu of manuals prepared in the training department.

Seventy-five percent of the companies have investigated the use of maintenance dependency charts, and 42% of the companies have investigated the use of job performance aids.

Sixty-three percent of the companies agreed that engineering controls technical manual schedules by its supply of data. Forty-two percent of all companies have someone who acts as liaison between engineering and technical manuals.

The approximate total number of equivalent pages delivered in FY 1971 by the reporting companies was 1.182 million units.

Ninety percent of the companies agreed that member companies should pool their knowledge to develop a better technical manual. Each would be willing to disclose its methods of program management with other companies doing the same.

Eighty-one percent of the companies make use of electronic data processing for parts of their technical manuals, including wire tabs and other suitable tabular data.

All but one company agreed that validation/verification is an effective means by which to check technical manuals.

Twenty-eight percent of all companies reported that current delivery requirements are not realistic.

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Fifty-one percent of the companies felt that their customer's UR system is not effective.

Eighty-four percent of the companies agreed that better supplier/user relations are needed. Lack of communication appears to be a problem.

Thirty-four managers, representing 34 companies, contributed to this report. These companies develop and manufacture electronics, airframes, missiles, machinery, and a miscellany of other product lines. With individual experiences ranging up to 30 years, these men were well qualified to contribute to this report.

In the companies surveyed, a total employment of 3813 persons was reported. The number of senior and junior writers varied for each company from a ratio of 1:5 to no junior writers employed.

The total selling price of technical manuals produced by the reporting companies in FY 1971 was \$62.35 million.

Over 90% of the companies do not require their writers to have college degrees. However, 75% of the companies do have minimum formal education requirements. These requirements may be waived if the prospective writer has had some military or industrial experience.

There is a lack of uniformity in the level to which technical manual management reports. The data indicates uncertainty as to where technical manuals should be structured in company organizations.

Over 90% of the companies attributed recurring management problems to in-house difficulties. Engineering appears to be the cause of some recurring problems, reported 33% of the companies; however, all of the companies indicated that engineering is aware of the problem areas of technical publications. Other problem areas include schedule slippage, adherence to a low budget, and lack of communications.

Eighty-eight percent of the companies have first hand knowledge of practices or procedures of the various military branches that contribute to higher cost or inadequate data in technical manuals prepared for them.

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